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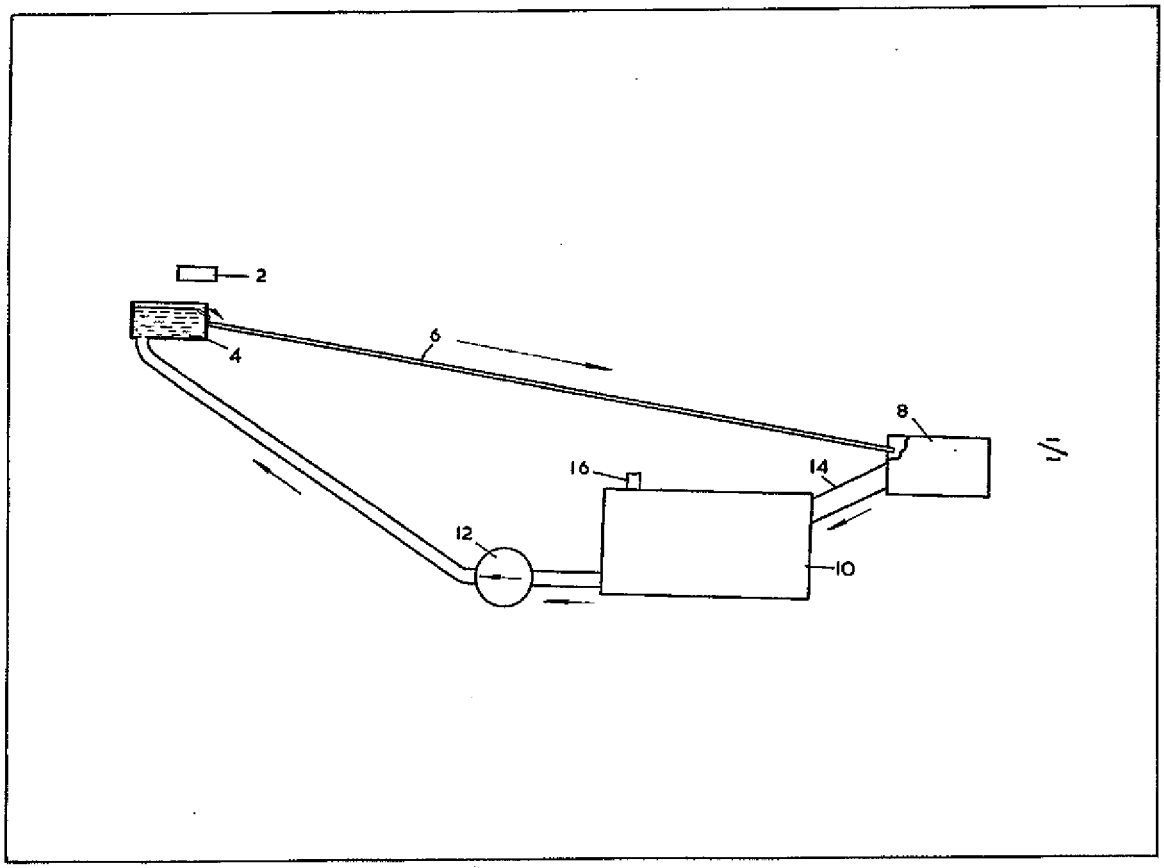
(54) **Freezing a liquid**

(57) A liquid, preferably cream, is frozen to produce solid pellets that can be stored, ready for consumption, in a refrigerator or freezer. Drops of cream are dispensed from a dispenser 2 and collected in a reservoir 4 of liquid nitrogen. The drops freeze to form buoyant, solid pellets of frozen cream. The buoyant pellets are carried by liquid nitrogen flowing under gravity from the reservoir 4 through a passage 6 into a separator 8 in which the pellets are separated from the liquid nitrogan, the pellets being received in the separator 8 while still buoyant. Liquid nitrogen separated from the pellets is passed into a sump 10, from which it is returned by a pump 12 to the reservoir 4. Eggs, cheese, yoghurt or blood may also be frozen.



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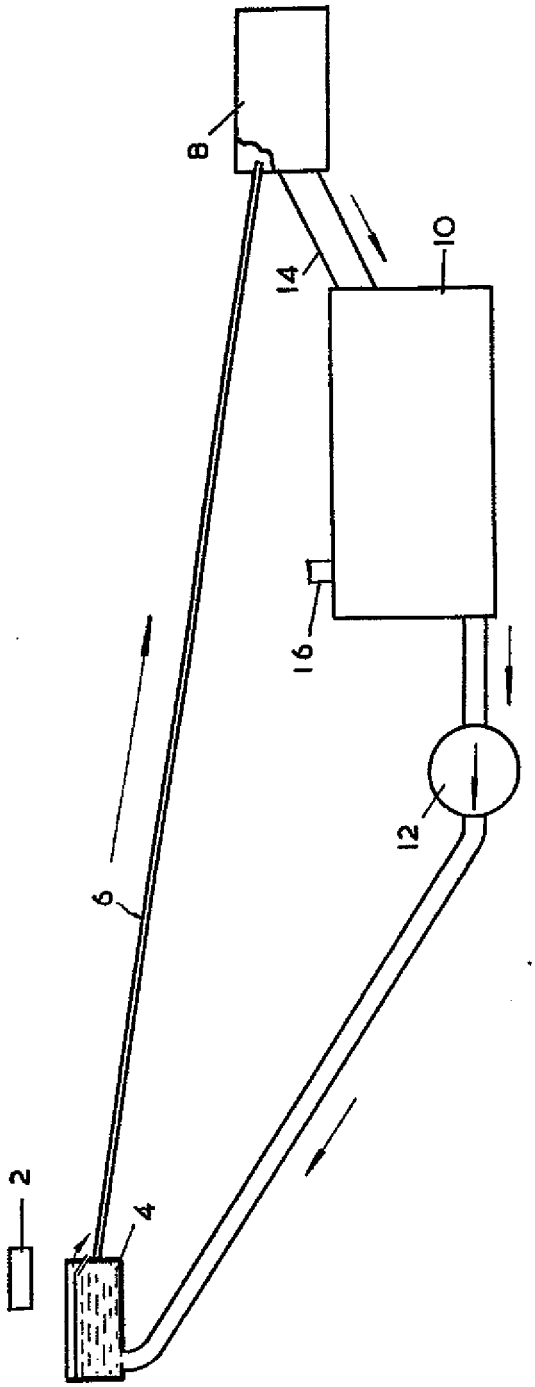
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SPECIFICATION

Freezing a liquid

This invention relates to freezing a liquid. The term 'liquid' is used herein to encompass emulsions; suspensions; solutions and semi-liquid foods such as cream, yoghurt, cottage cheese, butter, purees; products such as chocolate which are solid at ambient temperature but which melt at temperatures not greatly in excess of ambient; egg albumen or yolk (or a mixture of albumen and yolk), blood, and drug serums.

The invention is particularly concerned with the freezing of liquids that tend to deteriorate, eg. by virtue of chemical or bacteriological action, if stored for prolonged periods of time at ambient temperatures. An example of such a liquid is a diary product such as cream. Much cream is produced on farms or production centres remote from the eventual consumers. Difficulty therefore arises in keeping the cream fresh while it is being distributed from a place or production to a place of sale. A particularly efficient distribution system is required, and in general, cream has traditionally not been transported over large distances before sale. It has therefore been proposed to freeze the cream and store the frozen cream in a refrigerator before sale. This has made possible the export of cream from one country to another. For example, cream is frozen in slabs, the slabs broken down into lumps of more manageable size, and the lumps packaged in the Republic of Ireland and the resultant product is now on sale in England.

One disadvantage of such commercially practical cream freezing technology is that after being thawed the cream is not of such high quality as traditional fresh cream. For example, if the cream after being thawed (or while still frozen) is added to a hot drink (eg coffee), it tends to break down and leave an oily or fatty layer on the surface of the drink. This has led us to look for new methods of freezing liquids.

UK patent specification No. 1 264 439 relates to a frozen food substance comprising free flowing discrete particles of egg or semi-liquid dairy product (eg cream) wherein each said particle is of pop-corn-like form. The substance is produced by causing the egg substance or semi-liquid dairy product to fall into direct contact with a non-toxic, liquefied gas refrigerant having a temperature below −150°C and a turbulent surface. The substance sinks and the frozen substance is collected after sinking and is stored in a frozen condition. The liquefied gas is liquid nitrogen.

The process described in UK patent specification No. 1 264 439 suffers, we believe, from two disadvantages. First, a product of pop-corn-like form is readily crushed owing to its hollow thin-walled structure and there is a tendency for unacceptably large quantities of dust while being transported to a shop. Second, the process makes poor use of the refrigeration available from a liquefied gas such as liquid nitrogen. The reason for this shall be explained below.

Another process of interest is described in UK patent specification No. 1 376 972. The process it describes is limited to the production of a frozen food substance from egg. The egg is caused to fall from at least one nozzle into direct contact with a non-toxic, liquefied gas (for example liquid nitrogen) at a temperature of below −150°F. The flow rate of egg from the or each nozzle is from 1 to 5 lbs per hour so that the egg enters the liquefied gas from above its surface as discrete globules which are frozen therein to form pellets with the size range 3mm to 7mm. The pellets are collected at the bottom of the vessel containing the liquefied gas and removed therefrom. The liquefied gas adhering to the pellets is allowed to evaporate while maintaining the pellets frozen, and they are then stored in a suitable refrigerator.

In that pellets, as distinct from a pop-corn-like product, are produced the process described in UK patent specification No. 1 376 972 overcomes the first disadvantage associated with the production of frozen egg in the process described in UK patent specification No. 1 264 439. However, so far as overcoming the second disadvantage is concerned, the process described in UK patent specification No. 1 376 972 offers no improvement over that described in UK patent specification No. 1 264 439.

We have found that when drops of a liquid such as cream fall under gravity into a bath of liquefied gas such as liquid nitrogen the drops freeze to form discrete pellets. The pellets are initially buoyant. However, after a short period of time they lose their buoyancy and sink to the bottom of the bath. The loss of buoyancy coincides with a rapid fall in temperature of typically from about −10 or −20°C to well below −100°C. Thus, if the pellets are removed from the bottom of the bath in accordance with the teaching in aforesaid UK patent specifications they will be at a temperature well below −100°C. Since it will not be necessary to reduce the temperature of the pellets to −100°C or below, there is considerable waste of refrigeration and hence energy (since energy is required to produce liquid nitrogen) in cooling the pellets to such temperatures.

The invention aims at providing such method and apparatus for producing frozen pellets of a liquid that an excessive reduction in temperature of the pellets need not be occasioned.

According to the present invention there is provided a method of producing frozen pellets of a liquid, which method comprises the steps of causing drops of liquid to fall onto or into a volume of non-toxic liquefied gas having a boiling point below minus 30°C; allowing the drops to freeze to form buoyant pellets of frozen liquid and separating such pellets from the liquefied gas before they lose their buoyancy.

The invention also provides apparatus for producing frozen pellets of a liquid comprising a dispenser for dispensing the liquid in drops having at least one

The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

dispensing orifice; a vessel situated so as to receive the drops of the liquid in operation of the apparatus and suitable for receiving a volume of non-toxic liquefied gas having a boiling point below minus 30°C, and means for separating buoyant pellets of frozen liquid formed in the vessel from the liquefied gas, the apparatus being arranged such that in use the pellets can be separated from the liquefied gas before losing their buoyancy.

The liquefied gas is preferably liquid nitrogen.

The liquid may typically be dispensed under gravity, though if it is viscous a plunger may, for example, be employed to assist the passage of the liquid through the or each orifice. Typically, the or each orifice of the dispenser will tend to come into contact with cold vapour evaporating from the liquefied gas. In order to counteract any tendency for such cold vapour to freeze the liquid at the orifice, a relatively warm gas such as air (at or near to ambient temperature) may be blown or otherwise caused to flow across the or each orifice.

The pellets formed by the method according to the invention are substantially solid in contradistinction to the frozen food substance produced by the method according to UK patent specification No. 1 264 439.

The drops of liquid freeze and thereby form the pellets almost instantaneously upon coming into substantial contact with the liquefied gas. Initially, the pellets are buoyant and thus remain at or near the surface of the volume of liquefied gas. If desired, the pellets may be propelled across the surface of a stationary volume of liquefied gas by suitable mechanical means and received in a separator before the pellets lose their buoyancy as a result of their temperature falling to a level at which the pellets sink to the bottom of the vessel holding the liquefied gas. It is preferred, however, for a flow of liquefied gas to be established and for the buoyant pellets to be carried by the flowing liquefied gas. Accordingly, by providing at least one suitable passage leading to a separator, the pellets can readily be obtained free of the liquefied gas before they acquire a temperature sufficiently low for them to lose their buoyancy. The or each passage is preferably defined by one or more pipes or tubes. Preferably, the or each passage is arranged so that the flow of liquefied gas takes place naturally under gravity without having to be created artificially, eg by means of a pump. The pipe(s) or tube(s) are preferably in a coiled or spiral arrangement to enable them to be accommodated in a relatively small space. In an alternative embodiment, the passage may be defined by one or more troughs.

If the passage is defined by pipes or tubes the drops of the liquid may be caused to fall into a header from which the pipes or tubes are fed under gravity with the liquefied gas. If the passage is defined by a trough the drops of liquid may be caused to flow into or onto the flowing liquefied gas, preferably near the upstream end of the trough. The longitudinal axis of the base of the trough may be at a shallow angle to the horizontal with the inlet end of the trough the higher.

The separator may comprise a mesh which retains the pellets but not the liquefied gas. If desired, a rotary paddle-wheel may additionally be employed to lift pellets out of the separator so as to facilitate their separation from the liquefied gas. If desired, the liquefied gas may be returned to the inlet of the passage, and a pump may be provided for this purpose.

It is desirable for all the parts of the apparatus required to handle or come into contact with the liquefied gas to be contained within an insulated housing.

The temperature of the pellets is typically reduced to no less than minus 20°C. The time of residence of the pellets in the liquefied gas to give a suitable temperature reduction depends on the composition of the liquefied gas and the liquid. For freezing drops of cream in liquid nitrogen a residence time in the range 6 to 10 seconds is generally suitable. The temperature of the cream is preferably reduced to no less than minus 18°C.

We have surprisingly found that pellets of cream produced by the method according to the invention may be added to a hot beverage such as coffee without producing an unpalatable oily layer on top of the coffee.

The method and apparatus according to the invention may, for example, be used to freeze any of the liquids mentioned hereinbefore.

The method and apparatus according to the present invention will now be described by way of example with reference to the accompanying drawing which:

is a schematic diagram of an apparatus for freezing cream.

The apparatus shown in Figure 1 comprises a liquid dispenser 2, a liquid nitrogen reservoir 4, means 6 defining a passage placing the reservoir 4 in communication with a separatus 8, a sump 10 for collecting liquid nitrogen issuing from the separator 8 in use of the apparatus, and a pump 12 for returning liquid nitrogen to the reservoir 4.

The liquid dispenser 2 typically comprises a header having an inlet pipe (not shown) connectible to a source (not shown) of cream to be frozen. The header typically has rows of dispensing orifices (not shown) situated vertically above the reservoir 4 such that in operation of the apparatus drops of cream may be dispensed from the dispenser and fall under gravity onto the surface of the liquid in the reservoir 4. The dispensing orifices may each typically have a diameter sufficient to enable drops of cream 1.5mm in radius to be dispensed.

The drops of cream fall into the reservoir of liquid nitrogen and are frozen. Some liquid nitrogen vaporises and bubbles of nitrogen adhere to the frozen cream droplets thus keeping them buoyant.

Liquid nitrogen flows, typically under gravity, from the reservoir into the means 6 and then from the passage-defining means 6 into the separator 8. The means 6 may comprise one or more tubes, preferably spirally arranged, or one or more troughs. The arrangement is such that the frozen drops of cream remain buoyant and do not sink to the bottom of the passage as a result of the nitrogen bubbles recondensing.

The frozen drops of cream are separated from the

liquid nitrogen in the separator 8. The separated liquid nitrogen passes into a sump 10, via a passage 14. The sump 10 has an inlet 16 connected to a source of liquid nitrogen (not shown) to enable the sump to be replenished with liquid nitrogen to compensate for that which vaporises in operation of the apparatus.

The sump 10 has an outlet 18 in communication with the suction side of a pump 12 which returns liquid nitrogen to the reservoir 4.

The separated frozen drops of cream may be discharged from the apparatus by suitable means (not shown) associated with the separator 8 and collected in a suitable receiver (not shown).

The apparatus illustrated in the drawing may be located in a suitable thermally-insulated housing as to reduce the rate at which liquid nitrogen vaporises.

The frozen drops of cream are typically solid pellets.

CLAIMS

1. A method for producing frozen pellets of a liquid, which method comprises the steps of causing drops of liquid to fall onto or into a volume of non-toxic liquefied gas having a boiling point below minus 30°C, allowing the drops to freeze to form buoyant pellets of frozen liquid and separating such pellets from the liquefied gas before they lose their buoyancy.

2. A method as claimed in claim 1, in which the pellets are carried by a flowing volume of liquefied gas into a separator in which they are separated from the liquefied gas.

3. A method as claimed in claim 1 or claim 2, in which the temperature of the pellets does not fall below minus 20°C.

4. A method as claimed in any one of the preceding claims, in which the liquid is cream.

5. A method as claimed in any one of the preceding claims, in which the liquefied gas is liquid nitrogen.

6. A method as claimed in claim 4 and 5, in which the cream has a residence time of from 6 to 10 seconds, in the liquid nitrogen.

7. A method as claimed in claim 6, or claims 4 and 5, in which the temperature of the pellets does not fall to below minus 18°C.

8. A method for producing frozen pellets of a liquid substantially as herein described with reference to the accompanying drawing.

9. Apparatus for producing frozen pellets of liquid comprising a dispenser for dispensing the liquid in drops having at least one dispensing orifice; a vessel situated so as to receive the drops of the liquefied gas in operation of the appratus and suitable for receiving a volume of non-toxic liquefied gas having a boiling point below minus 30°C; and means for separating buoyant pellets of frozen liquid formed in the vessel from the liquefied gas, the apparatus being arranged such that in use the pellets can be separated from the liquefied gas before losing their buoyancy.

10. Apparatus as claimed in claim 9, additionally including at least one passage for conducting liquefied gas and the buoyant pellets from the vessel to the separating means.

11. Apparatus as claimed in claim 10, in which the or each passage is defined by a pipe or tube.

12. Apparatus as claimed in claim 11, in which the or each pipe defines a spiral.

13. Apparatus as claimed in claim 11 or claim 12, in which the vessel is a header from which, in operation of the apparatus, the tubes or pipes are fed under gravity with the liquefied gas carrying the buoyant pellets.

14. Apparatus for producing frozen pellets of liquid, substantially as herein described with reference to, and as shown in, the accompanying drawing.

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